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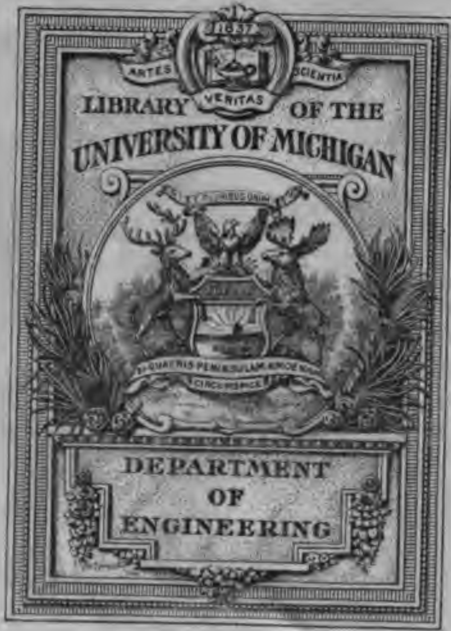
The Necessity for Individual Engineering Libraries and for Continuing Study After Graduation

AN ADDRESS
to the Engineering Students of the University
of Missouri and the University of Kansas

1908

BY
JOHN LYLE HARRINGTON
CONSULTING ENGINEER
KANSAS CITY, MO.



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THE NECESSITY FOR INDIVIDUAL ENGINEERING LIBRARIES AND FOR CONTINUING STUDY AFTER GRADUATION.

By John Lyle Harrington, Consulting Engineer.

Substantially every engineering graduate aims to achieve success along professional lines; otherwise his education is largely a mistake, for an engineering course, though it supplies mental training of a high order, offers very little that is cultural, while a well chosen academic course affords equal mental training and, at the same time, provides the broad, general culture which is so advantageous in every vocation. Fame and position may be attained as a technist purely; that is by confining the attention wholly to the design of engineering works; for cities, railroads, contractors, and the manufacturers of bridges, locomotives, engines, electrical apparatus, and other lines of machinery need such men and value them highly. Or, with a sound knowledge of the technical work for a foundation, success may be won as a salesman or as a manager of sales; as a publicity officer or advertising manager for manufacturing companies; as an engineering educator; as a manager of works and construction; as a business or contracting manager; or as an executive officer in any corporation whose business is based upon engineering.

Both money and position may be gained as a contractor in the construction of engineering works; and the field of technical journalism offers high rewards. But the highest professional position is to be gained as an engineer in the broadest sense of that term. This requires the greatest possible technical skill, both theoretical and practical, in some important specialty and its allied branches; and sound knowledge of the methods and the business features of construction, of the law of contracts, of the financing of engineering projects, and of accounting, including under that term not merely the bookkeeping relating to construction, but the consideration of operation, repairs, renewals, sinking funds, and similar financial matters.

Many qualifications are required for a high order of success. That one must have health goes without saying, for without health and strength there cannot be hard and continuous labor, either mental or physical; and success of any kind demands both. Intelligence is necessary to grasp the most abstruse principles of mathematics and the pure sciences and to apply them to available resources. Energy of the highest order must be employed to study principles, men, methods, and materials and to bring them together so that useful works shall result. Integrity is absolutely essential to high professional success; for the engineer's position is frequently judicial, and he must bring to his work all of the spirit of fairness that is given to man. The individuality and initiative to do original, thoughtful work is another essential without which the engineer becomes a hack or a grind who, though a useful cog in the machine, does little to advance his profession. But all these qualifications count for little in the struggle for professional success unless they are supplemented by a sound engineering education. Thirty years or more ago a great many eminent engineers obtained at least their technical education by their own efforts. Then the profession was comparatively undeveloped, technical literature was meagre, and it was much easier than it is today to learn all that was most important of any one branch of engineering. Self education is possible now, but it is rarely broad, and it generally fails at the critical moment. The man who has educated himself rarely has the training necessary to keep pace with the advancement of engineering science, and he is much more apt to be a "rule of thumb engineer" or a copyist than an original thinker. Nowadays graduation from an engineering school of good standing counts for so much that only the lower positions are, as a rule, open to the man who is without it. Graduation is a guarantee of a certain training, and employers demand it.

The technical course, however, is only the beginning of an engineer's education, the first stretch of a long and interesting but difficult road. The present requirements for admission to institutions of the first grade are as high as, too often higher than, the secondary schools are prepared to satisfy, and the four-year courses are crowded well nigh to the limit of the capacity of the average student; yet the engineering graduate is taught only the elements of a few important branches and is left substantially without knowledge of many subjects which are closely allied to any specialty he may choose. This is not the fault of the schools, for it is their function to perform the greatest possible service to the community which supports them, rather than to maintain certain ideals; but it is due to the inability or unwillingness of the student to spend the requisite time and energy upon his education. To raise materially the requirements for admission or to increase the length of the course would diminish greatly the number of students; and, while the few would be better prepared, the community as a whole would not be so well served.

There is at present a strong tendency to require more work of the engineering graduate. President Schurman of Cornell University is advocating a five-year engineering course, as Dr. Waddell has been doing for more than twenty years. Dartmouth and Cornell urge a special academic course which leads to a bachelor's degree and includes sound training in mathematics, languages, and the natural sciences, and which is followed by a two-year course in purely technical work, leading to the professional degree. Several institutions are offering five-year courses, and many provide a year's graduate work for those who are willing and able to prepare themselves more thoroughly than usual.

Engineering educators very generally recognize that our graduates are lacking both in culture and in breadth of technical knowledge; and they are earnestly seeking means for improvement. Some prominent professors are beginning to demand a collegiate education in preparation for the engineering study, just as such training is now required in many Eastern schools in preparation for the study of law and medicine; for it is evident that the engineer needs for his highest development more training, more and broader knowledge, and more culture than he commonly possesses. The enormous increase in the number of students pursuing technical courses ensures very keen competition in all branches of engineering; for, though the field is widening rapidly and during the recent period of remarkable prosperity the demand for engineers was greater than the supply, the day is not far distant when employers will be more at liberty than they have been to select men especially suited to their needs. Then the law of the survival of the fittest will operate more truly; and education and training will count for still more than they do today. Then, even more certainly than now, only the ablest and best educated men will sit in high places and ordinary talent will remain in the ranks.

Now I want to state in the most emphatic terms at command that, no matter how high the standard of your school, when you graduate your education is only well begun, that if you do not continue your studies with as much or more vigor than you have commonly employed, you will have exceedingly small chance to win fame or position. You will be left standing at the post, and the races will be won by men who know their deficiencies and who take prompt and energetic steps to remove them. Your shortcomings are not limited to ignorance of subjects you have not studied. As soon as you are called upon to apply commercially the technical knowledge acquired while in school, you will become painfully aware that both your best efforts and those of your instructors have not given you such command of the facts and principles of engineering that you can employ them with facility and assurance. During your course there was not sufficient occasion for applying the knowledge you gained to make its use a habit, and since completing the study of many subjects there has been time to forget much of them.

The great danger comes when you leave your *alma mater* and go out to take your place in the world. The man whose diploma is fresh is rarely given work which demands the immediate use of his theoretical knowledge, even that relating to one subject. The more mechanical work of drafting, inspection, or running an instrument is what he can do best, and, consequently, what he will be given to do; and it may be years before his duties attain such a breadth that the entire range of his technical knowledge will be called into play. When the demand does come it will come suddenly, and often it will be unrecognized. Then woe unto him who has considered his technical course all sufficient, for he will be like the foolish virgins in the parable, he will lack oil for his lamp and there will be no time to get it. He has not only failed to study and grow as the years passed, but he has lost a large part of the knowledge he spent four years to gain; and the prize is not for him.

Let me illustrate by citing a few of the many instances which have come under my observation. Though each case will show only a single failure, it will indicate clearly the general status of the knowledge possessed by the engineer in question.

One man, after six years in the bridge shops, could not calculate the stresses in a Warren truss produced by static loads. Another, after spending twelve years detailing and inspecting bridges, could not determine the stresses produced in a beam by a locomotive. Another who had spent eight years detailing bridges and structural work could not find the reactions from a simple cantilever crane. Still another of seven years' experience could calculate graphically with facility but could do nothing analytically. One man was found to be unable to make a stress sheet for a parallel-chord, Pratt-truss highway bridge, though he had spent nearly three years in one of the best bridge shops in the country. Another who had been employed for two years in the office of the bridge engineer of one of the prominent railroads could not find the position of two wheels which would produce the maximum moment in a beam. An electrical engineer of four years' experience, when working out some electric locomotive problems, considered the grade in per cent to be numerically equal to the degrees of angle between the track and the horizontal. This error ultimately cost him a position which afforded a salary of thirty-five hundred dollars a year. An experienced mechanical graduate was astonished to find that the speed with which steam will travel through a port is calculable. Another found it impossible to conceive that a steam turbine is operated by the impulse instead of by the pressure of steam. And I have known several experienced mechanical men who could not determine what series wound motor is required to hoist a given load through a fixed distance in a certain time, because they could not read the performance curves of the motors.

Since you may say these are isolated cases and, consequently, prove nothing, I shall cite one more which is so sweepingly general that it seems incredible. A prominent bridge company wanted another designing engineer. They employed about seventy men, substantially all technical graduates, in the detail drawing rooms. In the course of a few months the chief engineer tested every man of promise among them to see if one could not, in reasonable time, be trained to fill the position; but all so lacked theoretical knowledge or facility in its use that an engineer was obtained elsewhere at twice the salary received by the best paid man in the drafting rooms. Probably every man of the seventy would gladly have taken up the designing work for less salary than he was then receiving, but not one was prepared and ready.

I might cite many more such examples, but I think abundant have been presented to convince you that the technical education must be carried on vigorously and continuously after graduation, if positions much higher than those of skilled workmen are to be attained. Without exception, the men mentioned in the individual examples I have just cited were graduates of Eastern engineering schools of the highest standing. They had every advantage which you have now or will have when you graduate, unless you possess the energy and foresight to acquire and to study thoroughly and persistently a library of the best books, periodicals, and technical society papers which relate to your specialty and its allied branches. If you avoid this work and try to cope unaided with the many problems which will confront you, you must inevitably fail and occupy through life a very subordinate or at best a secondary position.

Let us examine the undergraduate course carefully in order to determine what it accomplishes, what are its limitations, and how you may, while still in school, strengthen yourselves against the day when you are turned out into the world to sink or swim professionally; when you no longer have within reach instructors ready to help you over the rough places and to guide and direct you at need.

The first two years are devoted almost exclusively to the study of mathematics, languages, and the natural sciences, subjects which afford culture and excellent mental training, and form the basis for the technical work, but are in themselves not at all technical. During this period the student's capacity for study and his ability to grasp a new subject are greatly improved, but only two years are left for the technical work; and it taxes the ingenuity of the faculty, and sometimes the strength of the student, to cover in that limited time all of the more important fundamental subjects relating to any branch of engineering. Many closely allied subjects must be left untouched, and there is time for only the elements of many of those considered. It is impossible in the time available to make a deep and comprehensive study of any one branch without neglecting other important subjects.

President Woodrow Wilson of Princeton University has recently argued before a meeting of teachers that our educational methods are all wrong, that we teach too many subjects and no subject thoroughly enough. There is a measure of truth in the statement, for it is better to be well versed in some one line, so well that the knowledge is constantly available for use, than to know something of many lines, but so little of any one that the knowledge is not of much service. It is always difficult so to draw the line between deep preparation and broad preparation that the greatest good will result. In fact no general rule will apply, but the courses must be laid down for the average student in accord with the faculty's best judgment. Some men would be benefited by more concentrated work, for they may tend naturally to breadth; on the other hand many men would, if possible, select easy work under the guise of seeking breadth, and thus fail to obtain the necessary training.

Most students desire and many engineers urge that more practice be taught, and that the relations between theory and practice be made clearer; but educators have wisely refused to comply with these demands, for to do so without increasing the time required for the course would crowd out essential theoretical studies which the graduate is not likely to pursue unaided. Students generally expect to be finished, practical engineers when they graduate; and many practitioners think that the schools should leave the graduates little to learn; but thoughtful engineers realize that the schools serve their highest purpose when the whole course is devoted to fundamental, theoretical studies and only enough practice is taught to illustrate principles. The training that results in the ability to grasp new ideas and in the habit of concentrating the mind upon any matter in interest is everything; the knowledge of a few facts more or less is nothing. Every time a student leads his instructors to believe he has mastered a point when he has not, he cheats himself not out of so much learning but out of the ability to learn. He has handicapped himself permanently for the sake of an hour of ease, left himself a little nearer the position of the untaught laborer, and depreciated a little more his chance for success.

As soon as he begins his professional work, the graduate commonly renounces all thought of further study of principles and devotes his whole time to the study of practice. Theoretical studies are commonly crowded out of his field of effort, and what he has not learned about them while in school generally remains unknown, therefore the technical courses offered nowadays are right in principle, since they are composed chiefly of fundamental subjects.

Neither would it be wise for the schools to permit specialization much, if any, more than they do now. It is rare for a student to know positively what branch of engineering he will make his specialty. Civil, mechanical, electrical, mining, chemical, and metallurgical engineering, each has many subdivisions so important that few can practice successfully in more than one or two of them; and it is difficult to know in advance of actual work for what branch one's taste or mental attainments best fit him, or in what line opportunities will occur; therefore the education should be so broad that any specialty may be chosen and practiced with success. It is not uncommon to find great deviation from the intended course, men educated as civil engineers practicing in mechanical lines, and mechanical engineering graduates doing civil or electrical work. Even if the specialty practiced could be predetermined, the advantages of special preparation for it, within the limits of the four-year course, would be more than offset by the narrowing effect of crowding out other important subjects; and an error in choosing a specialty would probably result in mediocrity or failure, for great opportunities do not occur frequently; and, if they cannot be seized promptly, they are generally lost. Therefore it is essential that your education be both broad and thorough, if the greatest success is to be obtained.

There is frequently a tendency for students to regard lightly the professional ability of their instructors, to consider them theorists who lack practical knowledge and whose opinions, therefore, must be accepted with caution. Once in a while there is reason for such an attitude, for the teaching branch of the profession is as subject to frailty as any other; but as a rule, these opinions spring from eagerness for practical work and the habit of regarding the theoretical studies as a necessary evil, a groundwork, which it will not be essential to recur to, once active practice is begun.

The true value of the scholastic work is not realized. It is frequent to hear objections on the part of the student to this or that study because it is not practical; because, so far as he can discern, it has no bearing upon designing and constructing engineering works, which in his opinion constitute the sum total of engineering. The study of English is especially subject to such criticism; just as though it were not necessary to employ the language understandingly in the preparation of specifications, contracts, and advertisements; in instructions to other engineers, to contractors, and to foremen; in technical papers and books; in business correspondence, prospectuses, estimates, reports, and other business papers, as well as in the social relations. It is singular how prevalent is the idea that this, the instrument most commonly used of all, the one upon the quality of which all others depend, should be considered of little consequence. If you have neither knowledge to gain nor thought to convey, the study of English is evidently useless; but, in that event, so is the study of every other subject.

An engineer, of all men, requires such knowledge of the technique of the language that he can use it with accuracy and facility at all times. The bad construction of a sentence, even the erroneous use of a word or the misapplication of a comma, may result in costly litigation and heavy loss; therefore the language merits far more study than the best technical courses provide. Even if you have excellent habits of speech and write good English readily, you will find, upon close study, that habit cannot be depended upon for satisfactory technical English. Close, careful study of diction and construction is essential in any case. The reading of well written technical works, of the English classics, and of the best current literature will aid greatly in the acquisition of correct habits; but this is not enough. Make the study of the language habitual or you will find, when you have advanced so far in your profession that you have engineering and legal papers to prepare, that you blunder grievously in your use of English. I know an engineer of unusual technical ability who has twice tried and twice failed to establish himself in independent practice, and who still occupies a secondary position, largely, in my opinion, because he speaks and writes like an ignoramus.

A knowledge of chemistry is likewise universally essential to the engineer, no matter what specialty he practice, for the relations of the constituents of the materials employed in construction are always important and often vital; and if they are not understood, the materials cannot be used intelligently.

Foreign languages are not technical subjects; but they aid in keeping one thoroughly informed; for only the best things to be found in them are translated into English, and the publication of the translation is commonly far behind that of the original.

Other subjects which do not deal directly with design and construction are required for similarly good reasons, which only active practice will make clear; therefore the student's objections to the subjects he is obliged to study are commonly illfounded, and if any of them are slighted during the course, in all probability it will be necessary to remedy the deficiency later.

As soon as possible after graduation the embryonic engineer obtains a position and enters upon his professional career. If he have a choice, he generally takes the one which pays the most money immediately, though the ultimate compensation in any branch of engineering is inversally proportional to the salary paid the beginner in it. If he has a well defined idea of what line of work he desires to follow, and if he has been fortunate enough to obtain a position in that line, he will probably employ all his energy to learn everything practical about his immediate tasks and whatever else comes directly under his observation. Often the work of more experienced men is studied zealously to the neglect of his own. He will, if he be energetic, drive with all his strength at the practical work and begin to calculate upon how soon his salary should be increased. If he is in the field, he sees skilled workmen paid much more than he is; and, because he knows the workmen have not his education and could not do his work, he exaggerates the value of his services and often begins to have a grievance. He does not realize that he knows very little about his broad line of work, while the skilled mechanic is well trained in his narrower line and, consequently, is better able to produce saleable results.

Almost every young engineer is inclined to minimize the amount he has to learn and to seek to reach the top in a few short leaps. I remember one very bright young man who entered the detail drawing room of a bridge company immediately after graduation. Within a month he applied for transfer to the designing rooms, because, as he stated, he had learned all there was to be learned about detailing. He was transferred; and for some months, under the impression that he was estimating, he contentedly calculated the weight of steel on lists furnished him by the designers. He learned so fast, in his own opinion, that it is not surprising that in eight years he has attained a very mediocre position. Every man who, when he graduates, thinks he knows all but a little of the practical work, which he can learn in a few months, will make similar progress unless some shock opens his eyes to the truth.

Though this extremely comfortable idea of the graduate's equipment is not very general, the estimate the young man usually places upon the extent of his knowledge is almost universally far too high. It is common to assume that the education is finished, that the text books are properly put away like other childish things, and that it is only necessary to go forth, learn practice, and conquer. And since that course requires the least possible amount of energy, it is very frequently followed for years; so long that when the need for further study is finally realized, the mathematics and the elements of the theoretical work obtained in school are forgotten, and the task of reviewing them and acquiring further knowledge of them is so great that it appals and discourages, and the man remains for the balance of his life a draftsman, an instrument man, or a secondary man of some other sort. He will attribute his own failure to the malice of enemies or the lack of powerful friends, and the success of his acquaintances to influence or luck. He will rarely admit, even to himself, that he failed because he deserved to fail, because he was unwilling to work for success. Is the picture distasteful? I hope so. But do not get the idea that it is exaggerated. I can call the names of many men whose advancement has been imperceptibly slow because they proceeded along such lines, and every engineer has watched the course of many who have been left behind because they would do only the work given them to do and would set and perform no tasks for themselves. And I have known many others who have gone forward rapidly because they think, read, and study continuously.

There are, of course, differences in the amounts and kinds of ability with which nature has endowed men, and it is very easy to attribute your own failure or another man's success to these qualities over which the individual has no control, but I firmly believe that by far the larger influence is common industry, or the lack of it. And I assure you it requires much more energy to think out a course of study and pursue it than it does to perform your daily task well. Energy is necessary to perform manual labor or routine mental labor, but infinitely more is required to do original work or to pursue a course which is not obligatory and which will result in no immediate benefit. It is the custom of mankind to forfeit large but long deferred benefits for the sake of small immediate ones.

When a young man takes up his first work, he gives his best thought, as he should, to learning to perform the tasks which will provide his living; and if he has not already a bit of a library and the habit of using it and increasing it, that is about all he will do except to satisfy his desires for recreation and for social pleasures. He has little immediate use for his books and he forgets them and their contents. His duties do not require knowledge of law or organization or management or business or finance. These are not, he concludes, engineering subjects, and, consequently, can be of no interest to him; therefore he gives them little or no thought. In the course of two or three years, if he has been industrious and thoughtful in his daily work, he will be given tasks which make greater demands upon his technical knowledge. Then he must go back to his text books and review them before he can with assurance do the work properly. This takes time, for he has forgotten much, and, in order to escape criticism for lack of facility, he will probably try short cuts or guess work and fail. This is the usual course, because men employed by large corporations generally acquire such extreme respect for the organization and for the opinions of their official superiors that they will adopt almost any means to avoid severe criticism. In the bridge shops, for instance, there is commonly a very un-American fear of "The Boss," which arises partly from the superior knowledge and position of the official and partly from the possibility of criticism for ignorance or, more commonly, for lack of industry and attention to business. It is deplorable but undeniable that technically educated men have to be watched and urged, much as the lower orders of workmen do. But haste due to fear of criticism and the laziness which prevents study frequently cause grievous blunders. False pride which prevents confession of ignorance is also a fruitful source of error. It takes courage and honesty to say, "I do not know," but courage and honesty are among the essential characteristics of a successful engineer.

I have said before that the engineering graduate is rarely called upon in the earlier stages of his professional work to use much of his technical information; and that, in consequence, he forgets it. This is especially true of those who take up field work. Their knowledge of instrument work is brought into immediate service, but in a very short time mechanics, the basis of all designing, will have become but a name. One of my acquaintances, who has spent in the field the most of his twelve years since graduation, recently told me that he was re-reading his mechanics and was astonished to find how little he knew of what was once thoroughly familiar to him. Undoubtedly he has learned much in field work, but he has actually lost ground in some lines and grown narrow. That is the usual course and the one certain to result in the man becoming a cog in the wheel and a little one at that. Many a technical man calls himself a bridge engineer and looks upon himself as a specialist who is cheated out of his dues; yet is versed in only one narrow branch of bridge work, such as shop drafting, inspection, or estimating. He probably knows little or nothing of shop work or erection or management or business or the higher technique of designing; yet he would bristle with indignation if you were to tell him he is narrow and that he does not know his business. He has steadily followed a single phase of a single branch of a single division of engineering, because up to a certain point he could increase his salary most rapidly by so doing. He became proficient in his narrow line of work, and he refused to take up other lines because he knew less about them and could earn less in them. And so he reached a certain position and remained there because his foundation was too narrow.

It is urgently necessary that the recent engineering graduate shall at once take steps to master thoroughly every phase of the specialty he means to follow, including many allied technical branches, and, at the same time, to broaden his view by studying other and more remote lines. There is so much to read and study, so many lines to pursue, that, unless he have the wisdom and foresight to work according to some plan, confusion and weakness will result. Knowledge is of value only as it is of use, and if it lack cohesion, is not gathered and arranged in the mind according to some system, it is almost useless. Many a man reminds me of my first shot gun. It made a big noise and kicked vigorously; whenever it went off you felt sure the game must come down; but it scattered so badly that it was rather more apt to miss than to hit. The shot would strike all around the bird, but it would often get off unhurt. Thus many a man shoots all around the mark but cannot concentrate his fire so it will tell.

Notwithstanding the necessary limitations of the technical course, if the student will do his part, he will, when he graduates, have the best equipment obtainable in the time employed. But he who performs his daily task and passes his examinations so well that he gets fair grades and in the end receives his degree, has not necessarily done his part. Good consistent work is much, but it is not all; in fact, it is only what the university demands in set terms. It obtains the credits and the degree, just as the ordinary laborer earns his daily wage; and it is little more likely to make the student an eminent engineer than the daily wage is likely to make the laborer a millionaire. Initiative and untiring energy to plan and carry out work which is not compulsory are even more essential and effective during the college course than they are at the height of the professional career. It is true that one who is only an ordinary student may awaken when he takes up his professional work and set for himself a pace which will enable him to reach the top; but as a rule he will never realize that he is not doing his best. He won his degree without great effort; and in his opinion, it necessarily follows that success must come naturally and easily. After a while, when it is too late, he finds it does not; then some one else or his luck is to blame, never himself. As a rule, it is easier to reform a drunkard than a drone or an indifferent man.

The graduate should understand that in spite of splendid equipment, able instructors, and rigorous discipline, the technical school does not turn him out a finished engineer, but leaves him to acquire the major part of the necessary technical knowledge after he has gone out into the world. It has given him methods of study, trained him to grasp readily the arguments of able writers, taught him the mathematics he needs, some foreign languages and something of his own, and the elements of some natural sciences, and it has made a beginning upon his technical education; but if he stops there, failure is certainly his portion. The school has accomplished its purpose, trained him mentally, but he must yet broaden and deepen his knowledge of theory, as well as learn the practical phases of his professional work. He must work alone. With rare exception his employers have neither the time nor the inclination to interest themselves in any portion of his life except that for which they pay. Occasionally he may be urged to exert himself to learn more about the work he is employed to do, but he must, of his own volition, plan and carry out the study which is essential to success.

The recent engineering graduate is not fitted to do much commercial work, and employers are loath to spend the time and patience necessary to direct him and to correct his errors. No one really wants to employ him, but he will be given place and work in the hope that ultimately he will become proficient and then repay in profitable service the time and effort spent upon him in the beginning.

If he be energetic, he will be encouraged to learn the things which will make his services more valuable immediately, the practical phases of his work. But what about the things which count so much toward his ultimate success, yet have no bearing upon the work in hand? Will they be pointed out to him? Will he be urged to study more deeply the courses he pursued while in school and to take up the study of the collateral subjects which have a bearing upon the work he will be called upon to do five or ten years hence? Yes, in about one case in a hundred. Surely not much more frequently. He will generally be left to his own devices except in so far as he can be made more useful now or in the very near future. In many large establishments even that much pressure is not brought to bear, but he is left to succeed or fail as he will. If he earn his salary and if work should be plentiful, he will be retained; but much personal effort to aid the novice is considered an immediate loss, for the average man will move on and deliver to another employer the benefit of such instruction as soon as he can obtain more money by doing so. Some of our larger manufacturers, it is true, seek recent graduates, bind them to a specific term of service, and maintain a course of instruction for them. In these cases the better men are selected for advancement in the company's service while the less competent or less energetic are retained as a sort of higher grade mechanic. I know one man who has been making shop drawings of plate girders for more than twenty years, for a mechanic's pay.

Even when employers or officers of corporations take a personal interest in the recent graduate and endeavor to advise him, they frequently find the effort wasted, if not offensive. Too many young men resent the advice to continue study as a reflection upon their intelligence and their equipment of learning. Sometimes egotism carries them so far that they think the older man is jealous of their superior knowledge; and the lofty manner in which they sometimes criticise the work of older men is often decidedly amusing. I well remember the uncomplimentary remarks two young graduates made about an eminent mechanical engineer and his design of a clam-shell bucket, though they did not understand even the operation of the machine.

Compare these conditions with those which obtain before graduation. The faculty not only urge the student to employ his best efforts and suggest better methods of study, but substantially compel him to acquire definite amounts of valuable information in a given time. He is not obliged to take the initiative. The courses are mapped out for him in detail; even the daily task is set; and if the ability or the energy to grasp any portion of the subject be lacking, the instructor not only stands ready and willing to aid when called upon, but seeks the opportunity to help. The student has constantly in view definite results to be attained in given periods; such as the completion, first, of the subjects immediately in hand and, finally, of the whole course, the receipt of a degree, and the entering upon a career which hope and imagination make brilliant. Every aid and incentive to study are offered. Pride in his own strength and in his ability to achieve, and the hope and encouragement of his family, his friends, and his instructors, urge him forward. The way is made easy, bright, and pleasant. He has only to follow the course laid down and honor and success are his.

Thus the student is aided and advised at every step, while the graduate must map out his own course and pursue it with energy and steady purpose, if he is to win. The transition is abrupt, the test severe; and it is little wonder that so many fail; but the remedy lies altogether with the student. He must take the initiative and so lay his plans and conduct his work that when he graduates there will be only a modification, not an interruption, in his course of study. He must prepare himself against the day of trial which is certainly coming, and take steps to supplement the university work.

Many of you, no doubt, consider yourselves hard worked to satisfy the faculty's requirements; but, except in the rare case when lack of health and strength interferes, you will find that a reasonable amount of collateral work is not only pleasant and profitable, but that it actually lightens the required work by affording a broader and clearer comprehension of it. And you have time for it. If you ever reach a high executive position, you will find that instead of taking your pleasure and recreation very much at will, as you do now, you will make them a part of a schedule which accounts for almost every minute of your time. You will often excuse yourself, instead of ceasing work, when a friend drops in for a social chat; and you will forego many a ball or dinner or theater party or other pleasure for the sake of your work or study. In time you will come to smile with amusement when you recall how you thought you were busy when in school. The student is father of the practitioner, and I know that very few young engineers understand how to concentrate their thought upon what they are doing so that only imperative matters will interrupt them. And still fewer take such a comprehensive view of their work that the little, less important features of a task are not forgotten or neglected. Therefore, I fear that the student who thinks he is hard worked has much to learn about methods of study.

Primarily, you must do the prescribed work with all your energy and ability, set your own pace in it rather than be driven or coaxed along, and bring yourself to understand that the training you are receiving and the habits you are acquiring now are of the utmost importance to you throughout your professional career. If it be possible to do more work than has been prescribed (and almost every earnest, energetic student will find it so) choose the work which you prefer or think most beneficial, seek your instructors' advice regarding it, and then do all of it you can without detriment to the prescribed courses. Purchase other books which cover the same ground as the text-books employed. They will often present the matter in different lights and actually reduce the amount of work required to grasp the subject. I recall that an old work on analytical geometry, which treats the problems graphically, greatly aided me to understand the algebraic treatment of the prescribed text book; and Prof. Merriman's books on bridges frequently made Johnson's clearer. Every book contains important matter which is not to be found in other works that treat the same subject. Often different methods are presented; and at the least, the second reading serves by repetition to fix the matter more firmly in the mind. The differences between like works in matter and method of presentation strengthen by bringing the judgment into play and training it, and by developing the student's habit of independent thought.

Again, to read in the technical journals and the proceedings of the engineering societies descriptions of such works as those of which the text-book or lectures treat, greatly aids in understanding the subject and in fixing it in the mind, and, at the same time, affords a glimpse of the connection between theory and practice. The reading of technical papers also teaches you where to find data and how to present them, and acquaints you with what is going on in the world. There is something new in every issue, something to excite your curiosity and stimulate your mind.

If the time and energy be available, it is very advantageous to purchase and read books relating to allied subjects which the prescribed course does not include. For instance, a thorough course in dynamo-electric machinery or in thermodynamics or in the metallurgy of iron and steel may be of great service to a civil engineer; and a course in architectural engineering, in mill building construction, or in masonry design is of the highest importance to a mechanical engineer. I recall a large rail mill roof designed by an able mechanical engineer, which had only itself and the wind and snow to carry, yet was strong enough to support a railway train as well. And a civil engineer's work in mechanical lines is often painfully crude. Yet the various branches of engineering frequently overlap; and any engineer should be prepared to do reasonably well work in other lines which are closely allied to his specialty. If the fundamental knowledge of these allied subjects can be obtained in course without interference with the regular work, so much the better, but sooner or later it must be obtained.

Yet the great value of the purchase and perusal of the technical periodicals and other than the required text books lies in beginning a library and in establishing habits of independent thought and study while still in position to obtain friendly aid and advice from the faculty. The files of the technical periodicals form a very important part of every engineer's library. Even the six or eight volumes of any good engineering paper which the student should accumulate afford many descriptions and illustrations of engineering works and of the methods of designing and constructing them. But the back numbers are difficult to obtain; and if the graduate does not have them, he is not likely to buy them, and, consequently, will miss their aid in solving his first practical problems. Without them his knowledge of what has been done in the engineering world will not extend much back of the day he began work in his first position.

It is true that there are one or two copies of each of the best technical journals in the school's library and that they can be read, even though they are not purchased. But they will not be read. How many of you read thoroughly even a part of one journal? How many read none at all? And if you should read them, that would not serve the purpose, for they and the technical society transactions constitute a large share of every engineer's library, and you should have them for reference.

After graduation many a young engineer would take up the study of subjects which bear upon his work but which he did not study in school, if he knew what books to buy. But, as a student, he has not learned to select books, for the text books have always been specified, and he knows little or nothing about the respective merits of others. And rather than waste his money on ill selections, he commonly makes the greatest of all errors by purchasing none at all.

It is difficult to estimate the ultimate value of a dozen books and a single engineering paper purchased and read during the course of study. The technical knowledge is increased, the habit of independent thought and methods of independent study are established, additional books are made familiar and available for reference, and the nucleus of a library is formed. The graduate has already begun his professional work; the transition from school to the office, shop, or field is made without danger that he will consider his education completed and that he will, in consequence, cease to study and grow. The size of this beginning of a library is of infinitely less importance than the habits formed in collecting it. The little group of books, if he carry them with him, will constantly strengthen and support him in his work and keep ever present in his mind the need for more books and further study.

Many a student, instead of taking pride in the growing row of books on his shelf, sells even his text books as soon as he has received his credits in the subjects of which they treat. He burns his bridges behind him and makes certain that whatever he has not learned from his books will remain unknown, whatever was not clear will remain obscure, whatever he forgets will remain forgotten. When, in his later work, either before or after graduation, his memory needs refreshing or a point puzzles him, he cannot turn to the familiar pages and satisfy his needs. Instead, in fear and trembling he puts on a bold face and endeavors to convince his instructors or employers that he knows what he does not know. If he succeed, he has cheated both himself and them and has acquired a dishonest habit. If he fail, and he generally does, though he may not know it, he not only acquires the dishonest habit and cheats himself, but he fails in his work and falls behind in the race. No other books will ever supply the desired information so readily as those he pored over in school. Even if the student has not the means or the foresight to begin his professional library by purchasing additional books, the required text books. if retained, form a valuable working nucleus. When the course is completed the days of a text book's usefulness instead of being over are only begun; and the man who sells his as soon as he can is already on the high road to failure.

It is frequently stated, sometimes by instructors, that the average student cannot afford to buy more books than are absolutely essential to the pursuit of the prescribed studies; but such a view is exceedingly narrow. Expenses vary greatly with the situation of the institution, the tuition charged, and the student's tastes, habits, and supply of funds; but four hundred dollars a year is probably a low estimate of the average annual expenditure, even in our state universities where the tuition is little or nothing. An increase of five per cent, or about twenty dollars per annum, spent for a good technical journal and for well selected engineering books will place within the students reach the means for doubling his fund of technical knowledge. And what can be said of the economy of spending a dollar for half a loaf when a dollar and five cents would buy a whole one! I feel sure that the cases are few in which the lack is not the money to buy books but the intelligence to appreciate their value and the energy to master their contents.

Consult your instructors regarding the best books in each line and make memoranda of their recommendations. Likewise consult instructors in other lines of which you would like a knowledge and make lists of the books they advise and the order in which such books should be studied. Get the catalogues of the principal publishers; they may be had for the asking; and see for yourselves what is available. Study well the reviews of new books as they appear in the technical papers. Then buy as many as you can find time to master without neglecting your regular studies. If it be only one each term, that is much; if two, that is much more. And remember that the mere possession of the book does not serve the purpose. It is like your mind, valuable directly in proportion to the use you make of it. There is no known method by which a knowledge of the contents of a book may be acquired without reading and study, though the contrary idea seems to be prevalent. Mere possession or laying on of hands will not suffice.

I hear many of you say you have no time for extra work, that your instructors demand it all and more. But how many of you do not absolutely waste a half hour a day? I do not mean how many withhold that much time from your studies and devote it to social duties or pleasures, to recreation, or to exercise, all of which are essential to right living; but absolutely waste it, doing nothing which affords either pleasure or profit. Yet a half hour a day devoted to books will enable you to read several ordinary volumes each term. And the value of so much work, in the knowledge obtained and the habits and training acquired, is almost incalculable. You have so much to read, there are so many subjects just touched upon or not included at all in your course, that the earlier you begin your independent work the better. If you wait till you have nothing else to do, you will never begin. You must make room for such work. You will find that doing only a little regularly will strengthen you and will rapidly increase your capacity for work, and you will be astonished to see how much a half hour a day well employed will accomplish.

The majority of engineering students have not found it possible to pursue wholly or in part an academic course, hence it is very important that they read as much as possible in non-technical lines. And much valuable knowledge and training in the humanities, in the languages, and in sociology and political economy and finance may be gained while reading for recreation.

In your reading while in school do not reach out too eagerly after the practical phases of your subjects. Remember that the theory is the more difficult part to obtain unaided and that after graduation you will be obliged to make special effort to gain further knowledge of it, while you will necessarily learn much of practice in the ordinary course of your work. Seek to establish the principles which form the basis of your future tasks as thoroughly as possible in your mind and to acquire all the knowledge of them your time and strength will permit. Build your foundations substantially, and the superstructure will be much more certain to serve its purpose.

The discussion of technical problems in the undergraduate engineering societies is a very effective means of developing sound methods, for it enforces precise and comprehensive thinking and necessitates the reading of the technical papers and other books than those required for class use. No one wishes to advance theories or make statements which are not supported by facts or sound logic, therefore earnest thought commonly precedes discussion or argument.

Immediately after graduation review thoroughly all your text books that bear upon your work. Then map out a course of technical study, select and purchase the books needed for it, and, if possible, devote to it a certain amount of time each day. You will be astonished to find that with an hour a day well applied you will cover more ground than you did with all your time while in school, for you acquire better methods of study and greater mental grasp with the passage of years.

At the same time, subscribe for at least one good engineering weekly and read it thoroughly. For a few years the whole of it should retain your interest, because you are still more or less in search of your place in the world, and therefore you should be familiar with many lines of work. A monthly, too, which offers a more general view of the entire field of engineering is worth your while, for it tends to broaden and to attract attention to lines which may have permanent interest. Such magazines frequently contain valuable matter relating to shop management and accounting that is hard to find elsewhere. In course of time it is well to increase the number of technical papers and to restrict the reading more closely to the subjects of your special interest, but too early specialization is narrowing and harmful.

As soon as you have read the principal books relating to your particular subjects, take up other and more remotely related lines, but always follow a plan; for variety without it will lead to weakness. At the same time the plan should be subject to whatever alterations more mature judgment dictates. Avoid reading whatever comes to hand. No knowledge is worthless; but a small fund of well ordered information is much more serviceable than a larger amount of haphazard, ill-rounded, unrelated knowledge. It is difficult, but essential to the highest success, to be both broad and thorough, "to know something of everything and everything of something."

Do not read superficially nor accept all you read as the truth, solely because some writer has had the courage to put the matter into print. Engineers are not agreed upon all points, and many statements which are made as though they were generally accepted are open to question, sometimes in error. They must bear the test of reason. If they do not, there is something the matter with them or with your reasoning, and it is well to determine positively which is at fault.

Read descriptions of designs and of methods of construction, in order that you may have ready for use the results of other men's thought and experience. You should profit by their errors; and frequently a new application of a method or a slight improvement upon it will effect much. Each generation of engineers must begin where the preceding left off, if we are to make progress. Yet each year engineers waste much labor by re-inventing and re-devising what has already been well done; and much money is squandered in repeating errors which should have taught a lesson, all through lack of familiarity with technical literature, or the lack of a library. Remember that progress is made by small increments and with much stumbling and many falls, rather than by spectacular leaps and bounds. Wonders are rarely found outside the columns of our sensation loving newspapers. And if you want to make all your strength and ability effective, do not ignore what other men have done, but employ their results honestly and freely as a basis for your own work. Acquire with the utmost dispatch and with much financial sacrifice, if need be, a well selected and comprehensive reference library. Obtain at least one good book upon each subject as early as possible; and buy the back numbers of the principal engineering journals and technical society transactions for a period of ten years or so previous to your graduation. You must be able to turn at need to the records of what has been done as well as to what other engineers are now doing, if you would save yourself labor and error. The field is not virgin and you are not pioneers. At the same time you must neither become a slave to precedent nor so fear falling into the errors of others that you fail to act on your own initiative. Only those who do nothing never make mistakes.

Immediately after graduation join the principal technical society in your own line, read the papers and discussions, and attend the meetings if possible. And as fast as your years and experience permit, move on to the higher grades of membership. This identifies you with your profession, places at your disposal the most advanced professional thought, acquaints you with the leaders among your professional brethren, and as soon as you are prepared to take part in the discussions, supplies the means for recording your own thought and aids you in establishing your own fame.

Read from the beginning all you can find relating to the lives and works of famous engineers. There is no greater source of inspiration, no more certain method of obtaining a well balanced understanding of the whole field of engineering, no surer way of gaining a knowledge of what qualities in men make for success. Much encouragement will be drawn from this source, and many a pitfall avoided.

Another neglected means of assistance is the miscellaneous papers prepared by professional men for the purpose of aiding the younger men to start aright and to pursue the best course. Addresses to graduating classes and papers relating to special engineering subjects frequently contain many valuable suggestions. Sometimes they are made available by publication in pamphlet form, in the technical press, or in book form. Dr. Humphreys, President of Stevens Institute of Technology, has published two volumes of papers written by himself and other prominent practitioners, many papers by Dr. Waddell and others have been presented in pamphlet form; and the engineering journals occasionally publish the important portions of able addresses and papers.

The public libraries in our larger cities are of material service in both technical and cultural lines. Their chief value lies in enabling you to examine books before purchasing them and in the reference books they possess. But is is well to remember that any book which is worth reading should be purchased, in order that it may be referred to or read again at pleasure; for no one can remember all he reads.

Supplementing the reading along purely technical lines, it is well to take up at a comparatively early period the sounder books relating to methods of accounting, shop and railway management, banking and finance, the laws of contracts, and the laws governing construction. A knowledge of all these subjects is absolutely essential to the engineer who reaches the top. Let me cite one or two cases in illustration. My firm was recently called upon to examine an important bridge, to report upon its condition, and to advise what would be the cost of a new single track structure, the cost of a double track structure, and the cost of a single track superstructure supported on piers which would ultimately carry another single track superstructure. The present traffic requires but a single-track, therefore it was also necessary to advise the client how soon the traffic must be sufficient to make a double-track structure necessary, in order to warrant the higher present cost of the second and third types of bridge, and how much of the cost in each case would be chargeable to maintenance and how much to improvements.

Some years since a railroad company by which I was employed was obliged to renew the superstructures of two bridges over the Ohio River. Navigation interests demanded wider channels than the old bridges provided; and before the War Department would grant permission to build new superstructures on the old piers, without increase of span length, it was necessary for me to prepare a statement showing what present payment the United States must make in order to compensate the railroad company for the increase in first cost of the larger span in one bridge and of a cantilever structure in the other, and for the increase in the cost of maintaining, and ultimately of renewing, the more expensive structures.

Such statements as these require for their preparation a sound knowledge of accounting, of funding, and of maintenance charges. Yet they are less complicated than many statements the engineers for manufacturers find it necessary to make.

The knowledge gained by all the reading we have considered is rendered much more available if the library be well indexed. There is a general index of engineering literature which should be purchased early; an excellent index of current technical periodicals appears in the *Proceedings* of the American Society of Civil Engineers; and the en-